2016 UDOT RESEARCH PROBLEM STATEMENT

Title: Electric Bus Advanced Battery Management System   **No. (office use):** 16.06.12

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UDOT Champion (suggested): Hal Johnson (UTA)

Select One Subject Area
- ☐ Materials/Pavements
- ☐ Maintenance
- ☐ Traffic Mgmt/Safety
- ☐ Preconstruction
- ☐ Planning
- ☒ Public Transportation

1. Describe the problem to be addressed.

Electric buses offer great potential for a sustainable future with lower overall cost of ownership and zero tailpipe emissions, especially with advancement of DC fast chargers and wireless power solutions to keep the buses moving on their routes. However, the battery pack continues to be the primary limiting factor in adoption due to limited performance and significant range reduction over time (>20% loss in less than 2 years). Capacity fade in battery packs leading to range reduction is due in large part to the pack being limited by the worst case cell in the pack, or the weakest link. And worse yet, that weakest link is treated the same in existing battery management systems as all the stronger battery cells, leading to the weakest cell degrading faster than all other cells. This program addresses the problems of range and lifetime and their impact on overall cost of ownership in electric buses.

2. Explain why this research is important.

Existing approaches to battery pack design are based on beginning of life and neglect the implications of range loss over time. For this, new models are needed to properly consider battery cell degradation and actual bus route drive cycles when specifying battery pack requirements and considering total cost of ownership for electric buses. Further, existing battery controls treat all cells the same despite differences among the cells that significantly impact cell degradation. New battery monitoring and control approaches are needed to maintain range on bus routes over the life of the system.

Our team has developed and validated a new battery management technology that extends battery lifetime by 50% and increases usable energy. The base technology, developed with funding from DOE ARPA-E, achieves its benefits by actively treating battery cells differently based on real-time state of health estimation, advanced physics-based battery cell models, and an innovative, cost-effective hardware architecture. We have developed a light duty vehicle-scale prototype of the system on a 7.6 kWh battery pack that has been undergoing long term evaluation at NREL for the past year.

This program is aimed at applying our prior results to both develop models that consider lifetime implications on electric bus design and to perform hardware demonstration of our advanced battery management technology on an electric bus. Hardware demonstration will be on a 20-passenger electric bus with a 60 kWh battery pack operated on the EVR test track at USU. The program will also include partnership discussions with industry to make the technology available to UTA.

3. List the research objective(s):

1. Define the relationship between battery cell degradation and battery pack requirements for specific bus routes.

2. Determine the benefit and payback period for applying the advanced battery management approach to electric buses.

3. Develop design methods for cost-effectively applying the advanced battery management system to large separated battery packs typical of electric buses.

4. Determine practical considerations and limitations in making the technology available for future UTA bus projects.

4. List the major tasks:

1. Collect drive cycle data from UTA bus routes and climate conditions over the year

2. Develop life models for electric bus battery packs.

3. Evaluate battery pack requirements based on drive cycle data and life models for existing technology and new advanced battery control approach.

4. Design, build and test battery management control hardware for the 60 kWh battery pack demonstration.

5. Integrate the battery pack hardware in the 20 passenger electric "Aggie Bus"

6. Evaluate electric bus battery pack performance and compare to models by operating UTA drive cycles on the Electric Vehicle

and Roadway (EVR) track at USU.

7. Develop reports and disseminate results and design models

8. Coordinate discussions with industry on path forward to incorporate the technology on future UTA bus purchases and retrofits (including Proterra and BYD)

5. List the expected results:

1. Electric bus models suitable for evaluating overall cost of ownership and battery pack requirements using drive cycle data and battery cell aging data.

2. Detailed analysis showing opportunity and payback period for UTA in expanding their electric bus fleet with and without the new battery management system.

3. Hardware demonstration of a 20-passenger electric bus with a 60 kWh battery pack using the advanced battery management system operated on the EVR test track at USU

4. Industry contacts with inputs on viability and estimates for cost and timeline in procurement of the battery technology.

6. Describe how this research will be implemented.

Dr. Zane will serve as overall project lead. Co-PI Dr. Jason Quinn will lead model development efforts. Ryan Bohm will serve as lead engineer at the EVR facility at USU. Graduate and undergraduate students will be involved in all tasks. The project leverages prior model and hardware results from the DOE ARPA-E program for light duty vehicles. The program will begin by evaluating UTA bus routes and conditions and updating vehicle battery pack models to incorporate the conditions typical of large distributed packs in electric buses. Design procedures will then be developed to evaluate battery pack requirements based on the models and bus routes. New hardware will be developed based on the existing light duty system, with updates for the larger format battery cells and interface requirements on the electric bus. All bus retrofit work and hardware system evaluation will be performed on the test track at the EVR. The team has existing contacts at Proterra and BYD that will be involved in the program for the industry discussions. Additional system integrator companies may also be contacted for discussion on retrofit opportunities.

7. Requested from UDOT: $50,000   **Other/Matching Funds:** $70,000   **Total Cost:** $120,000

    (or UTA for Public Transportation)

8. Outline the proposed schedule, including start and major event dates.

Start date: May 2016
End date: Jun 2017

Tasks 1-3: May 2016 – Dec 2016
Tasks 4-6: Jul 2016 – Jun 2017
Task 7: Jan 2017 – Jun 2017
Task 8: Sep 2016 – Jun 2017